The Valuation of Landfill Disamenities in Birmingham

By Yun Ham[a], David Maddison*[a] and Robert Elliott[a]

* Corresponding author

[a]Department of Economics,
University of Birmingham,
Birmingham B15 2TT
United Kingdom

Tel: +44 (0)121 414 6653
Fax: +44 (0)121 414 7377
Email: d.j.maddison@bham.ac.uk

Abstract

The disposal of waste by landfill generates community concerns, during both site operations and following the cessation of activities. Whilst previous hedonic studies have generally examined the impact on property prices of distance to the nearest active landfill site this paper presents a study for Birmingham in England in which properties are simultaneously located close to numerous active and historical landfill sites. Accounting for the proximity of historical landfill sites alters the perceived disamenity impact of active sites and furthermore, reveals evidence of significant disamenity impacts, decades after site closure, albeit over shorter geographical distances. Estimated disamenity impacts are however somewhat sensitive to assumptions regarding the geographical range of the externalities generated by landfill.

Keywords: Landfill; Waste; Hedonic Technique

1. Introduction

Recent years have witnessed significant changes in waste management policies in order to reduce the amount of waste generated and to encourage recycling, as well as addressing the perceived problem of over-reliance on landfill as a means of disposal. The amount of waste however appears ever-increasing and landfill remains the most prevalent method of disposal in many parts of the European Union, particularly the United Kingdom. There is moreover continuing concern that, despite the existence of measures like the landfill tax, the cost of disposing of waste through landfill is still priced at levels which fail fully to internalise the social costs.

The negative effects of landfill include emissions of methane, which is a potent greenhouse gas. Landfill leachate, generated when rainwater mixes with waste in landfill sites, may contaminate groundwater. The day to day operation of landfill sites can also affect nearby households through nuisances like noise, visual intrusion, odour, wind-blown litter, flies and vermin. Traffic to and from landfill generates noise, traffic congestion and localised air pollution. Proximity to a landfill site can also generate 'stigma' damages not attributable to any physical impact. Each of these impacts operates over a different geographical scale and may persist even after landfill sites are closed.[1]

Ignoring the fact that some impacts are global in nature, in an attempt to quantify the localised disamenity-impacts of landfill previous authors have often used the hedonic price technique. Starting with Havlicek et al. (1971) such attempts appear motivated by a desire better to inform policy makers of the true environmental cost of landfill disposal, thereby providing part of the information necessary to develop an optimal waste management program. But only a handful of studies exist outside the United States (e.g. Cambridge Econometrics, 2003).[2] Furthermore, not infrequently studies include only a limited number of structural and accessibility-type variables (for an exception see Ready, 2005). And critically,

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[1] Other costs of an overreliance on landfill disposal include the loss from not recycling valuable materials.

[2] This study pertains to Great Britain. For examples of studies undertaken in Africa see Arimah (1996); and Du Preez and Lottering (2009).

two issues remain inadequately researched namely the impact of site closure and proximity to multiple landfill sites.

Only five studies investigate closed sites (Halstead, 1997; Gunterman, 1995; Skabursis, 1989; Kinnaman, 2009; and Bouvier et al, 2000) and of these, two suggest no impacts on property prices, two studies point to negative impacts, and one provides mixed results. Furthermore, although it is of obvious interest to determine the time-profile of post closure impacts only Kinnaman (2009) contains a before-and-after study of property prices, including data from the period 1957-2005 for a single site that closed in 1976. No study address the question of whether the geographical limit of disamenity impacts changes once a site is closed.

Studies utilising microeconomic data have studied either single sites or combined data from different areas each containing a single active or inactive landfill site. Only one has dealt with a situation in which a large number of properties are simultaneously located close to more than one landfill site (Cambridge Econometrics, 2003). By contrast, four studies using aggregate data account for the existence of multiple sites e.g. the number of landfill sites within a municipality (Blomquist et al, 1988; Ketkar, 1992; Clark and Nieves, 1994; and Brasington and Hite, 2005). But these studies do not include any historic sites and their reliance on aggregate data implies a significant loss of control in the hedonic price regression.

The contribution of this paper therefore, is twofold. First, using microeconomic data this study investigates the impact of landfill on property values in the context of what we regard as the 'standard case' in which properties are often simultaneously located close to more than one landfill site. This is achieved by combining GIS data on landfill sites taken from the Environment Agency with data on housing transactions in Birmingham in England compiled by Bateman et al. (2004). Second, by distinguishing between historical landfill sites according to when they closed we investigate the time profile of disamenity impacts following the cessation of landfill activities. We also investigate whether the geographical extent of disamenity impacts changes following site closure.

To anticipate our main findings it appears that, at least in the case of Birmingham, accounting for proximity to multiple historical landfill sites alters the estimated disamenity impact of active landfill sites. This occurs because active and historical landfill sites are often located next to one another. Furthermore, historical landfill sites appear to depress property prices for many decades after their closure, albeit over shorter geographical distances.

The remainder of the study is organised as follows. In the next section, we provide a suitably brief overview of the hedonic pricing technique. The third section reviews the empirical evidence on the impact of proximity to a landfill site on property values. The fourth section describes the dataset used in the current exercise. Section five describes our methods whilst section six presents the results. The final section concludes.

2. The hedonic price technique

Housing consists of a bundle of structural, neighbourhood, accessibility and environmental attributes.[3] Any property can therefore be fully described by the vector *Z*:

$$Z = (z_1, z_2, ..., z_J)$$

where *z* describes the level of each of *J* different housing attributes. Given the stock of housing, property prices are determined by the interaction of supply and demand and the price *P* of any given house will be determined by the vector *Z* describing its attribute levels:

$$P = P(Z)$$

Given the hedonic price function, hedonic theory then considers how individual households choose the optimal bundle of housing attributes. Assume that household utility *U* is determined by the consumption of a composite commodity *X* with price equal to 1 and the vector of housing attributes *Z*:

$$U = U(X, Z)$$

The budget constraint is:

$$M - P(Z) - X = 0$$

where M is income. The first order necessary condition with respect to housing characteristic z_j is:

$$\frac{(\partial U / \partial z_j)}{\lambda} = \frac{\partial P(Z)}{\partial z_j}$$

[3] The hedonic price technique and its application to the housing market are extensively discussed elsewhere (e.g. Palmquist, 1999 and Freeman, 2003).

where λ is the marginal utility of income. This equation states that marginal willingness to pay for z_j must equal the implicit price of an additional unit of z_j. Identification of the demand curve for z_j however requires additional information on how households possessing known socioeconomic characteristics would react to a different set of implicit prices (Brown and Rosen, 1982).

The hedonic technique assumes buyers have full information concerning the price of housing and attribute levels, as well as the absence of transactions costs, which may prevent households from relocating to a more preferred site. In addition, unless a continuum of housing-attribute levels is available households may have to choose a house which does not satisfy the first-order conditions of utility maximization (Maler, 1977).

Estimating the hedonic price function involves controlling for all those attributes affecting the price of property. Since theory does not provide an exhaustive list of relevant housing attributes there is however, an omnipresent risk of inadvertently excluding important ones thereby inviting bias and inconsistency or, more benignly, including redundant ones risking only inefficiency. The cross sectional data used in hedonic analyses may also exhibit spatial autocorrelation if important omitted attributes are spatially correlated.

Empirical analysis also requires selecting an appropriate functional form for the hedonic price function. Since the repackaging of housing attributes is typically impossible the hedonic price function may be nonlinear suggesting use of the semi-log or log-log specifications. Use of the Box Cox transformation is also commonplace (see e.g. Halvoresen and Pollakowksi, 1981). It is important to test whether the observations are drawn from a segmented property market and hence whether it is appropriate to fit two or more piecewise regressions to the data (Straszheim, 1984).

3. Literature review

Accessing ECONLIT on 1st June 2010 a total of 59 journal articles, working papers and dissertations were identified containing the words 'hedonic' and 'waste' anywhere within the abstract.

The earliest hedonic analysis of the disamenity impacts of landfill appears to be Havlicek et al. (1971) which, like almost all subsequent studies, uses distance to the nearest landfill as a proxy for the disamenity impact (see also Havlicek et al., 1985). An adverse impact of landfill is also detected in Hockman et al. (1976) and Gamble et al. (1982). Employing a slightly different methodology, Research and Planning Consultants Incorporated (1983) compare the price of property near to a landfill site with that of comparable property elsewhere (see also Petit and Johnson, 1987). Nelson et al. (1992) estimate the effect of an active landfill site on nearby house prices and Ready and Abdalla (2003) present a method for testing the geographical limits of landfill impacts. Some studies examine the impact of landfill sites on the change in property values over time (see Goldberg, 1972; Groth, 1981; and Greenberg and Hughes, 1992). For a critique of such studies see Bleich et al. (1991). Note also that a number of researchers find no evidence of disamenity impacts from active landfill sites whereas others perverse results (e.g. Schmalensee et al., 1975; and Gamble and Downing, 1984).

Some papers focus on changes in the risk presented by particular landfill sites. Adler et al. (1982) and Cook et al. (1984) analyse property prices both before and after the discovery of site contamination. Kohlhase (1991) emphasises the importance of public awareness. Smolen et al. (1992) examines the impact of a proposal for a low-level radioactive waste site. Other interesting 'before-and-after' studies include Wise and Pfeifenberger (1994) and Reichert (1997). Some studies like Schulze et al. (1986) include risk perception variables. Hite (1998) uses survey data pertaining to four landfill sites with differing life-expectancies.

Other studies focus on the long-term effects of landfill on property values testing for any reduction in property values even after closure. Guntermann (1995) uses interactive dummy variables to identify active landfills. Halstead et al. (1997) examines 'stigma-related' damages from an inactive landfill site. Skaburskis (1989) focuses on identifying the geographical extent of landfill impacts. Bouvier et al. (2000) measures the disamenity impacts of six sites of which two were open and the remainder either closed or inactive. Using data on house sales in a small community adjacent to a single landfill Kinnaman (2009) compares the impact before and after closure.

Another strand of the literature examines the impact of landfill characteristics on disamenity impacts. Thayer et al. (1992) compare the disamenity impact of hazardous and non-hazardous waste sites. Baker (1982) compares the impacts of municipal and industrial waste landfill sites. Ready (2005) examines three active landfill sites of varying size. Wang (2006) reanalyses Ready's (2005) paper correcting for spatial correlation. Lim and Missios (2007) find larger landfill sites have a correspondingly greater disamenity impact. Hite et al. (2001) studies the same sites as Hite (1998) but investigates landfill life expectancy. Michaels and Smith (1990) demonstrate the potential importance of accounting for market segmentation. In Nelson et al. (1997) market segmentation is by house price (see also Zeiss, 1984; and Reichert et al., 1992).

Whereas most hedonic studies use microeconomic data a few use aggregate data. In Ketkar (1992) the independent variable is median house prices in a municipality and the variable of interest the number of hazardous landfill sites (see also Brasington and Hite, 2005). Other hedonic studies investigate the value of a wide range of environmental (dis)amenities including landfill sites but not as the main focus (see e.g. Blomquist et al., 1988; and Clark and Nieves, 1994).[4][5]

Because of their geographical focus we review the final two studies in greater depth. In Great Britain Cambridge Econometrics et al. (2003) investigate landfill impacts using 300,000

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[4] There are also studies which use contingent valuation or related survey-based methods to investigate the relationship between landfill and property values.

[5] Cartee (1989) summarises three early studies. Brisson and Pearce (1995) review both hedonic and contingent valuation studies for a variety of waste disposal sites including landfills and incinerators. Ready (2005) conducts a meta-analysis to estimate a varying price effect across landfills of different sizes, using the results on marginal implicit price and varying features of 13 landfills studied in 9 articles. For high-volume landfills which accept 500+ tonnes per day, house prices increase by 5.92 percent per mile while for low-volume landfills it was 1.18 percent per mile.

observations relating to transactions occurring between 1991 and 2000. Each house was matched to one of seven different property types and 40 socioeconomic and neighbourhood variables. Landfill data include 5,828 sites in England and Wales and 1,300 in Scotland operational during the period 1993 to 1995. The hedonic price regression includes variables measuring distance to the nearest landfill and aggregated landfill volume within 0-0.5 miles, 0.5-2 miles and 2-3 miles. Scotland has the largest disamenity effect from landfill with a 40 percent reduction in house prices occurring within 0.25 miles whereas elsewhere the West Midlands displays only a 1.25 percent reduction in house prices occurring within 0.25 miles. The average reduction across Great Britain as a whole is 7 percent within a 0.25 mile radius. Landfill impacts diminish with the age of (active) landfills.

Although Bateman et al. (2004) focuses primarily on noise pollution, proximity to landfill sites is also included in their hedonic analysis. Using data for Birmingham they examine the impact of distance to the nearest landfill site on property values across different housing markets segmented on the basis of demographic and socio-economic variables. The results indicate that landfill impacts are not consistently negative across different markets. The positive impact in some areas is attributed to omitted variables.

Whilst both Cambridge Econometrics et al. (2003) and Bateman et al. (2004) are the most closely related to our study – particularly the latter since we utilise their dataset – neither of them take into account proximity to historical landfill sites.

4. Data

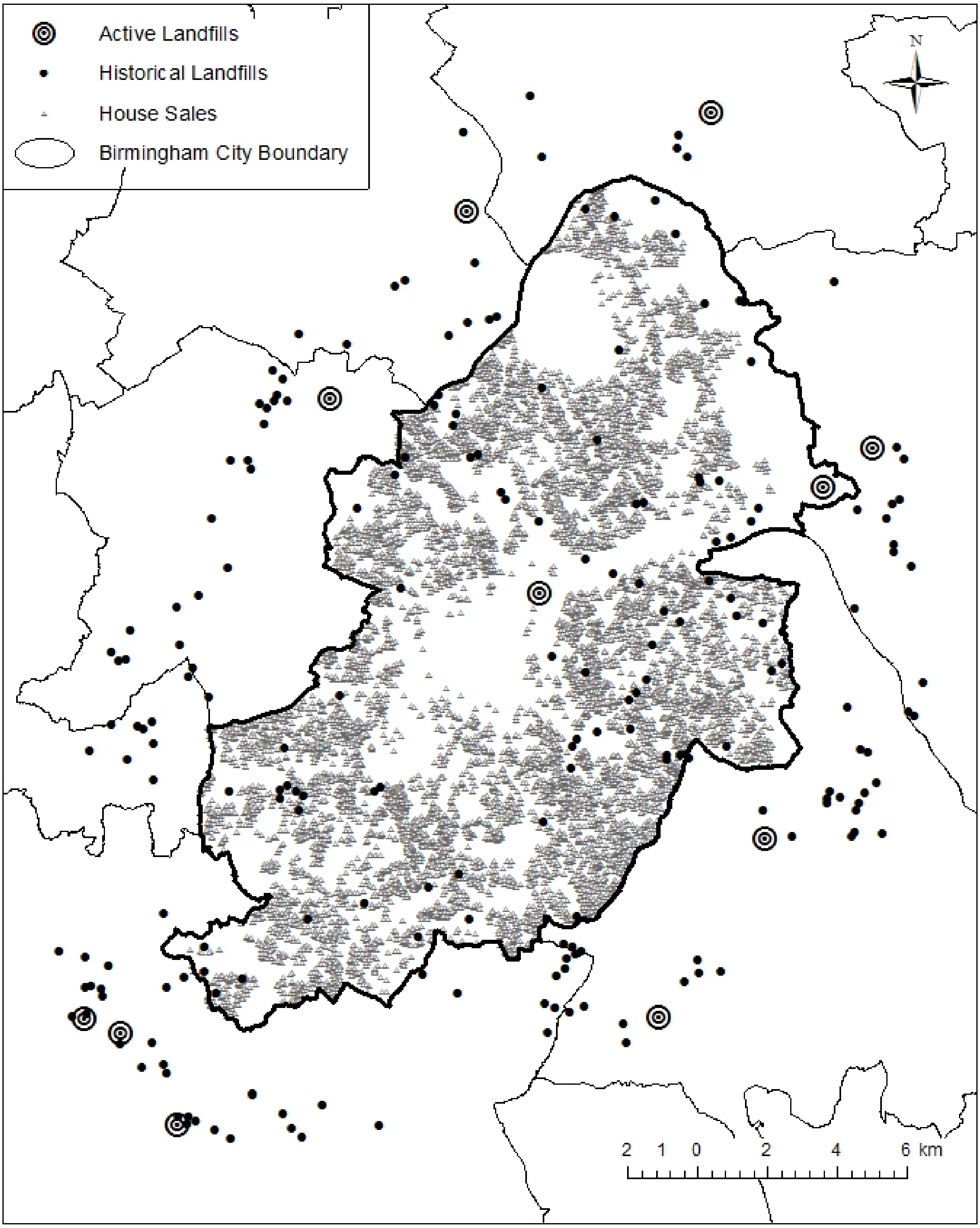
For the purposes of our analysis we use the data collected for a hedonic study of noise nuisance in Birmingham in 1997 published by Bateman et al. (2004).[6] To this data we add additional information pertaining to the location of active (in 1997) and historic (i.e. having closed before 1997) landfill sites in the West Midlands, the region in which the city is located.[7]

Bateman et al. (2004) obtained from the Land Registry records of all property sales within the City of Birmingham. The data includes the market price of the property, the date of the transaction and the address of the property. The dataset includes only residential property and ignores right-to-buy transactions which may not reflect the full market price of the property. Using the grid reference of each property these observations were then matched to a range of explanatory variables. The resulting dataset contains 10,792 properties. Figure 1 displays amongst other things the location of properties and the city boundaries. Those areas where no sales are recorded are mostly parks, golf courses, nature reserves, industrial areas and at the city boundaries, agricultural land. The dataset does however exclude city centre flats due to lack of noise data.

[6] This paper is later summarized in Day et al. (2007).

[7] Comparing national house prices with those for Birmingham there is no exceptional movement in house prices. Neither are there any reports of landfill incidents in Birmingham in the 1990s.

Figure 1: Location of properties and landfills within 4 km of Birmingham



Structural variables defining the physical characteristics of the property were obtained from the Valuation Office Agency (VOA). These include floor space, the number of WCs, bedrooms, the number of floors, the number of garages and garden area. Note however that some potentially important housing attributes included in other studies are missing e.g. the physical condition of the property, the degree of insulation and whether or not central heating has been installed.

The dataset includes straight line distance to disamenities (measured in kilometers) that are mostly related to noise and air pollution and visual disamenity, specifically landfill sites, industrial sites A and B, mosques, motorways, A, B and minor roads and railway lines.[8] The dataset also includes walking time (measured in minutes) to the nearest park, train station and the University / Queen Elizabeth Hospital. Lastly, the dataset includes driving time (also measured in minutes) to the central business district, the nearest motorway junction and the airport.

Information on the type of construction and the Beacon Group (BG) was also included. BGs refer to property types as defined by the VOA. The dataset includes 8 types of construction e.g. ‘detached bungalow’ and 18 BGs e.g. ‘un-renovated cottage pre 1919’.

The socio-demographic and economic characteristics of local neighbourhoods were taken from the 1991 census by the Office for National Statistics (ONS).[9] The smallest census area is the enumeration district (ED). In our dataset 1,743 different EDs are separately identified. Four variables reflecting unemployment, family composition, age structure and ethnically-concentrated neighbourhoods were selected. In addition to neighbourhood variables, also included are dummies for each of the 39 electoral wards in the city of Birmingham in order to account for possible submarket heterogeneity. These are displayed in Figure 2.

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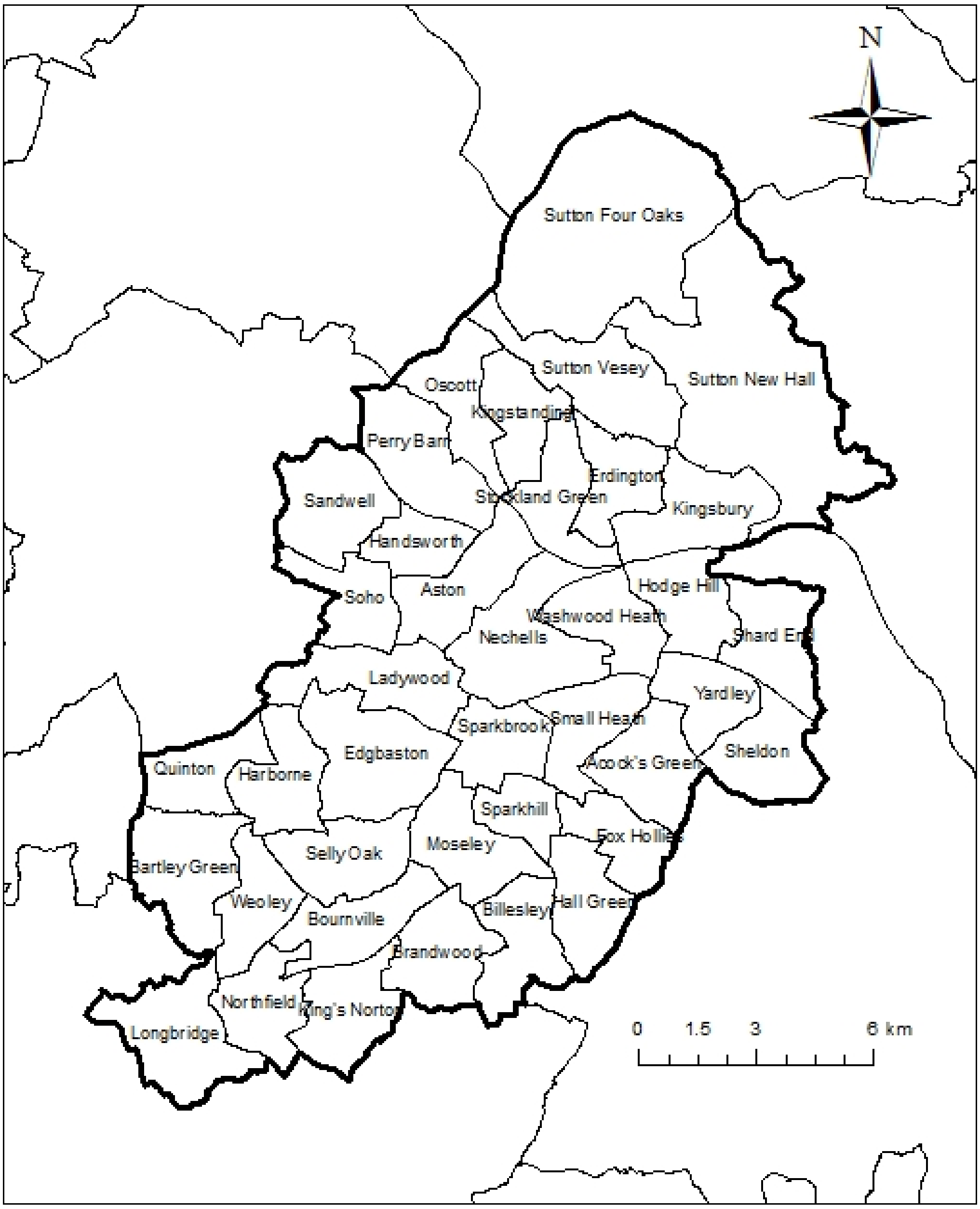
[8] Sanders et al. (2010) points out that use of straight line distance can lead to undervaluing open space in hedonic analyses. However, in the case of sites generating noise, odour, visual intrusion and air pollution, and not the subject of recreational visits, we think that people are far more likely to perceive proximity in terms of straight lines rather than the road network distance.

[9] There is little difference in the values of the socio-demographic variables between the 1991 and 2001 census. Birmingham becomes slightly more ethnically diverse although white is still by far the major ethnic group.

Figure 2: Wards in the City of Birmingham



The number of shops was taken into account using the formula:

$$A_i = \sum_{j=1}^{J} \alpha_j e^{-\delta d_{ij}}$$

where A_i is accessibility at property i, d_{ij} is the walking distance in kilometres between property i and shop j, δ is an exponent for distance decay and J is the number of shops in the region. Bateman et al. (2004) set $\delta = 2$ (such that a shop 100m from the property receives a weight over 6 times that of a shop 1 km away; and shops over 2 km away receive almost no weight at all) and $\alpha_j = \alpha = 1$ (such that all shops are considered equally attractive). Accessibility to primary schools was computed using the same procedure. For each primary school in Birmingham an estimate of school quality was calculated as the percentage of pupils achieving Level 4 or above in Science, Mathematics and English (the level expected of 11 year olds). The primary school accessibility index was then constructed with the weight α_j set to this measure of school quality and $\delta = 1$ (such that a school 100m from the property receives a weight over 2.5 times that of a school at 1 km distance and schools at over 4 km distance receive almost no weight at all). The values of δ chosen are those commonly used in accessibility research (Bateman et al., 2004).

Four land uses are identified specifically water, parks, roads and railway. Whether a particular property possesses a view of a particular land use was determined by taking account of the height of land upon which the property was built and the location and height of surrounding buildings. Road and rail noise data pertaining to 1999 were obtained from the Birmingham 1 project which comprises gridded noise contour maps for each source of noise measured in decibels (DETR, 2000). Aircraft noise for each property was taken from an aircraft noise contour map of Birmingham International Airport compiled in 1999. Air quality was assessed by Birmingham City Council (WMCOJPG, 2000). Concentrations of nitrogen dioxide and carbon monoxide were computed for every 250m×250m grid square based on 1998 traffic flows and other point sources of emissions. Table 1 provides summary statistics for all variables in the dataset.

How do the variables contained in this dataset compare with those used in published studies? Starting with Willis and Garrod (1992) virtually all hedonic analyses undertaken in the United Kingdom using microeconomic data include information on the total floor area and the number of bedrooms and bathrooms, along with other features of the property such as the presence of a garage, a garden and the existence of central heating (missing from the present dataset). Also invariably included are dummy variables describing the type of property e.g. terraced house or detached. Fletcher and Raeburn (2003) use in addition the more detailed BG descriptions provided by VOA. Indicator variables often identify property sales occurring in different periods of time (e.g. Rosenthal, 2006). Regarding environmental quality Tomkins et al (1998) include information on noise from aviation. Noise from other forms of transport and levels of air pollution by contrast are seldom included in United Kingdom based analyses. Gibbons and Machin (2003) focus on the quality of primary schools as a determinant of house prices. Gibbons (2003) focuses on the educational attainment, ethnicity, age profile and rate of unemployment present in the local community. Gibbons et al (2011) include a large number of accessibility-type variables e.g. distance to transport various links and also the city centre.

Table 1: Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Dependent variable				
Price(£)	58,996.09	36,253.55	9,500	645,003
Structural characteristics				
Floor Area (m^2)	102.586	32.707	42	645
Garden Area (m^2)	225.97	208.454	0	5,164.21
Age(decades)	6.481	2.66	0	10
Bedrooms	2.961	0.669	1	12
WCs	1.216	0.438	1	5
Floors	2.007	0.248	1	7
Garage	0.435	0.496	0	1
Sales date				
1st Quarter	0.213	0.409	0	1
2nd Quarter	0.245	0.43	0	1
3rd Quarter	0.287	0.453	0	1
4th Quarter	0.254	0.435	0	1
Construction type				
Detached Bungalow	0.013	0.111	0	1
Semi-Detached Bungalow	0.008	0.09	0	1
End Terrace Bungalow	0	0.022	0	1
Terrace Bungalow	0	0.017	0	1
Detached House	0.115	0.319	0	1
Semi-Detached House	0.396	0.489	0	1
End Terrace House	0.115	0.319	0	1
Terrace House	0.353	0.478	0	1
Beacon Group				
BG1 Unrenovated cottage pre 1919	0	0.019	0	1
BG2 Renovated cottage pre 1919	0.001	0.027	0	1
BG3 Small “industrial” pre 1919	0.04	0.195	0	1
BG4 Medium “industrial” pre 1919	0.226	0.418	0	1
BG5 Large terrace pre 1919	0.006	0.078	0	1

BG8 Small “villa” pre 1919	0.02	0.138	0	1
BG9 Large “villa” pre 1919	0.009	0.093	0	1
BG10 Large detached pre 1919	0.003	0.058	0	1
BG19 Houses 1908 to 1930	0.011	0.103	0	1
BG20 Subsidy houses 1920s and 30s	0.14	0.347	0	1
BG21 Standard houses 1919-45	0.257	0.437	0	1
BG24 Large houses 1919-45	0.016	0.124	0	1
BG25 Individual houses 1919-45	0	0.022	0	1
BG30 Standard houses 1945-53	0.045	0.207	0	1
BG31 Standard houses post 1953	0.19	0.392	0	1
BG32 Large houses post 1953	0.032	0.177	0	1
BG35 Individual houses post 1945	0.001	0.036	0	1
BG36 “Town Houses” post 1950	0.004	0.062	0	1
Wards				
Acock's Green	0.039	0.194	0	1
Aston	0.015	0.123	0	1
Bartley Green	0.018	0.131	0	1
Billesley	0.027	0.162	0	1
Bournville	0.038	0.191	0	1
Brandwood	0.022	0.147	0	1
Edgbaston	0.02	0.14	0	1
Erdington	0.029	0.168	0	1
Fox Hollies	0.028	0.165	0	1
Hall Green	0.041	0.198	0	1
Handsworth	0.016	0.125	0	1
Harborne	0.036	0.186	0	1
Hodge Hill	0.024	0.154	0	1
King's Norton	0.016	0.125	0	1
Kingsbury	0.01	0.101	0	1
Kingstanding	0.022	0.146	0	1
Ladywood	0.014	0.118	0	1
Longbridge	0.023	0.15	0	1

Moseley	0.024	0.152	0	1
Nechells	0.019	0.137	0	1
Northfield	0.028	0.164	0	1
Oscott	0.026	0.158	0	1
Perry Barr	0.033	0.18	0	1
Quinton	0.024	0.152	0	1
Sandwell	0.028	0.164	0	1
Selly Oak	0.044	0.205	0	1
Shard End	0.02	0.138	0	1
Sheldon	0.021	0.144	0	1
Small Heath	0.028	0.164	0	1
Soho	0.018	0.135	0	1
Sparkbrook	0.013	0.111	0	1
Sparkhill	0.021	0.142	0	1
Stockland Green	0.028	0.166	0	1
Sutton Four Oaks	0.038	0.190	0	1
Sutton New Hall	0.044	0.206	0	1
Sutton Vesey	0.039	0.194	0	1
Washwood Heath	0.028	0.164	0	1
Weoley	0.017	0.13	0	1
Yardley	0.024	0.153	0	1
Neighbourhood characteristics				
Age60+ (%)	20.86	7.79	2.97	64.2
Unemployment (%)	11.79	8.55	1.03	50
White (%)	82.34	23.141	4.95	100
Black (%)	4.30	0.056	0	42.83
Asian (%)	13.36	0.2	0	90.67
Family with children (%)	31.46	10.16	2.94	84.27
Accessibility characteristics				
Primary schools	0.602	0.177	0.15	0.97
Shops	2.279	1.275	0.07	9.56
Rail Station (mins)	30.763	16.881	0.351	92.081

Park (mins)	15.009	9.298	0.053	57.078
University / Queen Elizabeth Hospital (mins)	137.13	73.228	0.917	339.293
Central Business District (mins)	21.872	7.972	3.467	53.118
Motorway Junction (mins)	16.228	6.3	0.171	38.92
Airport (mins)	39.799	10.913	10.037	73.098
Mosque (km)	2.686	1.765	0.00001	9.036
Industry A (km)	2.462	1.82	0.022	10.204
Industry B (km)	0.814	0.528	0.010	3.333
Motorway (km)	3.761	2.074	0.030	8.370
Road A (km)	0.529	0.442	0.006	2.459
Road B (km)	0.659	0.522	0.005	3.401
Minor Road (km)	0.016	0.02	0.002	0.639
Railway (km)	0.809	0.556	0.006	2.778
Environmental characteristics				
Water View (m^2)	0.479	7.541	0	348.63
Park View (m^2)	6.289	36.83	0	664.03
Road View (m^2)	18.05	9.7	0	101.54
Rail View (m^2)	0.584	3.89	0	196.95
Road Noise (dB)	49.84	9.444	31.6	75.8
Rail Noise (dB)	36.81	12.557	0	74.7
Airport Noise Night (dB)	2.058	10.211	0	64.42
Airport Noise Day (dB)	4.764	16.045	0	69
NO_2 ($\mu g/m^3$)	89.593	26.655	50.4	410.84
CO ($\mu g/m^3$)	2.174	0.92	0.48	5.51

Only rather rudimentary information on landfill sites was included in Bateman et al. (2004). As explained above much more detailed data on landfill sites in the West Midlands were obtained from the Environment Agency. These data provide information on geographical coordinates, dates of first and last waste accepted, the type of waste buried and waste control measures taken (if any). Understandably the data is somewhat patchy for landfill sites that closed a long time ago.

Tables 2 and 3 contain information on historical and active landfills respectively within 4 km of houses sold in Birmingham in 1997. In 1997 the total number of landfill sites within the city boundaries was 53 comprising 51 historic and 2 active sites. There were however many more landfill sites in areas just beyond the city boundaries. Figure 1 displays all landfill sites located within 4 km of houses sold in Birmingham in 1997. In total 210 historic sites and 11 active sites are included in the analysis.

Due to missing information on either the opening date or the closing date the period of operation is missing for about 42 percent of historic sites. Excluding these missing observations, the average period of operation year was 15 years and the maximum 81 years. The oldest site for which records are available opened in 1904. Of the 16 active sites, the number of years of (ongoing) operation is on average 11.5 years and the maximum is 20.5 years.

Table 2: Operation of historic sites inside and outside Birmingham

Number of years operated	Frequency			
	Inside	Outside	Total	Percent
Up to 5 years	7	39	46	21.90
6-10 years	9	10	19	9.05
11-20 years	9	16	25	11.90
21-30 years	7	6	13	6.19
31-40 years	5	2	7	3.33
41-50 years	4	2	6	2.86
Over 50 years	3	3	6	2.86
Unknown	37	51	88	41.90
Total	81	129	210	100.00
Average number of years	20.53	12.01	15.08	
Maximum number of years	81.05	79.05	81.05	

Table 3: Operation of active sites inside and outside Birmingham

Number of years operated	Frequency			
	Inside	Outside	Total	Percent
Up to 5 years	1	1	2	18.18
6-10 years	1	2	3	27.27
11-20 years		4	4	36.36
Over 20 years		2	2	18.18
Average number of years	5.71	12.79	11.5	
Maximum number of years	7.79	20.54	20.54	

5. Methods

Previous hedonic studies have typically sought to estimate the impact of active landfill sites on the price of nearby properties using the following equation (or close variants thereof):

$$\ln(PRICE) = \alpha + \sum_{k} \beta_k Z_k + \gamma DIST$$

where the dependent variable is the natural log of the price of property (PRICE) and Z is a vector of k structural, neighbourhood, accessibility and non-landfill environmental characteristics. The key variable of interest, DIST, represents distance to the nearest (active) landfill. Quite often this variable acquires a constant value beyond a cut-off point beyond which disamenity impacts are (expected to be) negligible. Identifying the most appropriate cut-off point requires experimentation. The coefficient γ is expected to be positive.

An alternative functional form for the hedonic price function in which γ is expected to be negative is given by:

$$\ln(PRICE) = \alpha + \sum_{k} \beta_k Z_k + \frac{\gamma}{DIST}$$

With this functional form it is unnecessary to specify a particular distance beyond which the disamenity impact is (expected to be) negligible. This functional form does however involve making rather rigid assumptions about the rate at which landfill disamenities decay as distance increases.

Another functional form for the hedonic price function offering greater flexibility uses dummy variables to identify properties located in j different concentric circles with the site at the centre e.g. 0-1 km; 1-2 km etc is:

$$\ln(PRICE) = \alpha + \sum_{k} \beta_k Z_k + \sum_{j} \gamma_j ZONE_j$$

Unfortunately none of these specifications seems well-suited to a situation where properties are simultaneously located near many landfill sites. But, as we have already argued, and as Figure 1 suggests, this is likely to be important using property price data from a metropolitan area. Furthermore, even though there are relatively few active sites there are numerous historic sites each potentially generating long term post closure impacts. And because such impacts may lessen over time it may be necessary to distinguish historic landfill sites according to when they ceased operation.

In order to account for a large number of historical sites four distance bands were created: 0-1 km; 0-2 km; 0-3 km and 0-4 km. Beyond 4 km landfill impacts are assumed to be negligible. Separate variables provide a count of the number active and historic sites within each of these distance bands. The number of historic sites within each of these distance bands was further subdivided according to the following closing dates: 1-10 years ago, 11-20 years ago, over 20 years ago; and closing date unknown. In what follows therefore we run the following regression:[10]

$$\ln(PRICE) = \alpha + \sum_k \beta_k Z_k + \gamma ACTIVE_i + \sum_j \delta_j HISTORIC_{ij}$$

where $ACTIVE_i$ refers to the number of active landfill sites within distance band i and $HISTORIC_{ij}$ refers to the number of historic landfill sites within distance band i and which closed within a particular period of time denoted by j (note that we run separate regressions for different distance bands). The coefficients γ and δ_j represent the average proportionate reduction in house prices per landfill site within distance band i.

Table 4 contains descriptive statistics for the landfill variables. It reveals for example, that properties will on average have 0.16 sites that closed 11-20 years ago within a 1 km radius

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[10] The negative effects of a landfill may also vary depending on its characteristics such as cumulative quantity of waste or type of waste accepted. In addition to geographical information the data on landfills derived from the Environment Agency enables us to identify characteristics of some landfills like type of waste accepted and the number of years operated. But compared to the information on the date when sites closed this information is much less complete and there is no information available on the quantity of waste contained within in each site.

(with a maximum value of 2 such landfills for at least one property in the dataset). And if this radius is expanded to 3 km then the expected number of landfill sites increases to 1.55 (with a maximum value of 6 such landfills for at least one property in the dataset).

Table 4: Definition of distance bands

Variable	Definition	Mean	Std. Dev.	Min	Max
Distance band i = 0-1 km					
ACTIVE	Number of active sites	0	0.04	0	1
HISTORIC	Number of sites closed j = 1-10 years ago	0.13	0.37	0	3
HISTORIC	Number of sites closed j = 11-20 years ago	0.16	0.41	0	2
HISTORIC	Number of sites closed j = 20+ years ago	0.41	0.61	0	3
HISTORIC	Number of sites closed j = date unknown	0.29	0.59	0	3
Distance band i = 0-2 km					
ACTIVE	Number of active sites	0.03	0.17	0	1
HISTORIC	Number of sites closed j = 1-10 years ago	0.53	0.78	0	5
HISTORIC	Number of sites closed j = 11-20 years ago	0.70	0.90	0	4
HISTORIC	Number of sites closed j = 20+ years ago	1.56	1.26	0	6
HISTORIC	Number of sites closed j = date unknown	1.22	1.13	0	5
Distance band i = 0-3 km					
ACTIVE	Number of active sites	0.12	0.33	0	1
HISTORIC	Number of sites closed j = 1-10 years ago	1.10	1.08	0	5
HISTORIC	Number of sites closed j = 11-20 years ago	1.55	1.39	0	6
HISTORIC	Number of sites closed j = 20+ years ago	3.30	1.87	0	9
HISTORIC	Number of sites closed j = date unknown	2.68	1.48	0	8

Distance band i = 0-4 km					
ACTIVE	Number of active sites	0.30	0.48	0	3
HISTORIC	Number of sites closed j = 1-10 years ago	2.04	1.66	0	14
HISTORIC	Number of sites closed j = 11-20 years ago	2.75	1.90	0	9
HISTORIC	Number of sites closed j = 20+ years ago	5.48	2.55	0	14
HISTORIC	Number of sites closed j = date unknown	4.69	1.84	0	11

6. Results

Four different econometric models are presented in Table 5. These models are distinguished by differing assumptions concerning the appropriate distance band for experiencing disamenity impacts.

Beginning with the 0-1 km distance band (Model 1), the majority of structural characteristics are statistically significant at the one percent level of confidence. Property prices are increasing with respect to both floor space and also with the size of the garden. Even over a period of only 12 months also apparent is a strong upward trend in property prices. The age of a property significantly reduces its price by around 2 percent per decade. By contrast, the number of bedrooms and bathrooms is statistically significant at only the ten percent level of confidence. The presence of a garage adds 7 percent to the price of a property. Property type provides a highly significant explanation of the variation in property prices. Relative to a semi-detached house, most types of property were cheaper, particularly end-of-terrace bungalows which were 25 percent less expensive. Detached houses were 13 percent more expensive.

The BG provides a supplementary explanation of the variation in property prices. Most of the BG dummies are statistically significant at the one percent level of confidence. Relative to BG21 (referring to standard houses built 1945-1953) individual houses 1919-1945 (BG25) were 66 percent cheaper whilst renovated cottages built before 1919 (BG2) were 24 percent more expensive.

Turning now to neighbourhood variables, unemployment reduces property prices by 0.08 percent per 1 percent increase in the unemployment rate. Greater percentages of Whites and Asians in an ED increase the price of property. By contrast, neither the proportion of families nor the proportion of individuals over the age of 60 provides a statistically significant explanation of the variation in property prices.

Many electoral wards exhibit property prices higher than those encountered in Acock's Green (the electoral ward used as the baseline). Of these, Sutton Four Oaks was the most expensive area with property values 50 percent higher while houses in Soho were about 25 percent cheaper. To conserve space in the coefficients of the wards have been suppressed (these are available upon request).

Greater distance from the nearest motorway junction, mosque, type-A industry and railway line significantly increases property prices suggesting that these are disamenities.[11] Distance to Birmingham's central business district and to the nearest park, both commonly used accessibility variables in previous studies, were insignificant. By contrast proximity to an A road, a railway station, the University of Birmingham / Queen Elizabeth hospital increases property prices indicating that these are amenities.

Greater accessibility to the shops lowers property prices. This may be connected to increased traffic congestion and parking restrictions. By contrast greater accessibility to good quality primary schools is an important amenity.

Other than for landfill sites, most environmental variables are not significant except for a variable describing whether or not the property had a view of the railway, and a variable measuring the noise from road transport. In addition, air quality measured by average NO_2 concentrations has the wrong sign which may be due to the correlation between air quality and car ownership (i.e. NO_2 is a proxy for wealthy neighbourhoods).[12]

The number of active landfill sites within 0-1 km is negatively signed, but not statistically significant. The number of historical sites having closed 0-10 years ago, 11-20 years ago and 20+ years ago are however all significant at the one percent level of confidence. The number of landfill sites whose closing dates are unknown is not statistically significant, even at the ten percent level of confidence.

We now turn to our second model (Model 2) in which the distance bands for landfill impacts are expanded to 0-2 km. Because the results for the non-landfill variables appear insensitive

[11] The difference between Industry A and Industry B is that whereas the former are regulated by the Environment Agency the latter are regulated by the Local Authority.

[12] In the study of Mitchell and Dorling (2003) for example, electoral wards exhibiting high multiple car ownership have elevated NO_2 concentrations and there is an overall inverse relationship between car-ownership and pollution. The correlations between road, rail and aircraft noise show little correlation with CO or NO_2.

to the distance bands for landfill impacts we do not discuss these further and instead focus attention on the landfill variables. The number of active landfills becomes significant at the one percent level within 0-2 km but is, contrary to expectation, positively signed. The number of historical landfill sites closed 11-20 years ago is negatively signed and statistically significant at the one percent level of confidence. The distance bands for historical sites that closed 1-10 and 20+ years ago are not statistically significant along with the number of historical sites whose closing date is unknown.

Increasing further the distance band for landfill impacts from 0-3 km (Model 3), the coefficient on the count of active landfill sites is now negative and statistically significant at the one percent level of confidence. The coefficient on historical landfill sites closed 0-10 years ago, however, now becomes positive and statistically significant at the one percent level of confidence as is the coefficient on the number of landfill sites closed 20+ years previously. By contrast the coefficient on the number of landfill sites closed 11-20 years ago is negative and statistically significant at the five percent level of confidence whilst the number of historical sites whose closing date is unknown is statistically insignificant at the ten percent level of confidence.

Increasing still further the distance band for landfill impacts from 0-4 km (Model 4), the coefficient on the variable describing the number of active landfill sites is now statistically insignificant at the ten percent level of confidence. The coefficient on historical landfill sites closed 0-10 years ago is however positive and statistically significant at the one percent level of confidence, as is the coefficient on the number of landfill sites closed 20+ years previously. The coefficient on the number of landfill sites closed 11-20 years ago and the number of historical sites whose closing date is unknown are both statistically insignificant even at the ten percent level of confidence.

What these results make clear is that the impact of additional landfill sites – whether active or historical – is sensitive to assumptions made about the geographical extent of their impacts.[13]

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[13] Our explanation for the sensitivity of the coefficients of the landfill variables to assumptions regarding the appropriate distance band is that Models 1-4 force the geographical range of externalities from active and historical landfill sites to be the same. We

Some attempt therefore must be made to identify the ‘best’ distance bands for both active and historic landfills. The best distance band was identified by running all possible combinations of distance bands and making a selection on the basis of goodness of fit. Table 6 shows the adjusted R^2 of each combination. The best combination of distance bands (underlined in the Table) appears to be 0-3 km for active sites and 0-1 km for historic sites implying that the disamenity impact from active landfill sites extends over a much greater distance than the disamenity impact from historical sites. These results are displayed as Model 5 in Table 7. The coefficients indicate that for active sites the price reduction was 2.6 percent per site within the distance band 0-3 km whilst the impact of historic sites on house prices within the distance band 0-1 km ranges from 2.4 percent to 3.4 percent per site for those sites whose closing date is known with certainty. All of these impacts are signed as expected and statistically significant at the one percent level of confidence. Given the average sale price of property in Birmingham in 1997 these impacts amount to £1,534 for a property within 0-3 km of an active site and range from £1,416 to £2,006 for a property within 0-1 km of a historical site depending on when it closed. There is however no statistically significant impact for landfill sites whose closing date is unknown.

Diagnostic tests reveal a possible problem with functional form. In order to explore the significance of this we conduct a Box-Cox transformation of the dependent variable in Model 5. The transformation suggests the ‘theta’ parameter takes a value of 0.1887 and that it is moreover statistically different from zero at the one percent level of confidence (results not shown). Whilst this result enables us to reject the semi-logarithmic model the results for the variables of interest are virtually identical with the coefficients on both the active and the historical landfill sites negatively signed and, apart from the coefficient on active sites, statistically significant at the one percent level of confidence. The statistical significance of the coefficient on active sites falls from the one percent to the five percent level of confidence. We nevertheless prefer the results of the semi-logarithmic model merely for ease of interpretation.[14]

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also investigated whether the omission of various interaction terms could account for the sensitivity of the coefficients but this did not resolve the problem.

[14] The results presented in Table 6 are unaffected by the Box Cox transformation – the combination of a 1 km distance band for historical landfill sites and 3 km distance band for active sites is still optimal.

It is interesting that the impact of landfill sites on house prices appears to endure over periods in excess of 20 years after closure. It is nevertheless possible that these impacts refer not only to the impact of historical landfill sites per se, but also the fact that such sites have, perhaps deliberately, subsequently been earmarked for other undesirable land uses not otherwise controlled for in this analysis. It is also possible that currently active landfill sites will when they finally close, display shorter-lived impacts because of tightened regulations pertaining to their post-closure management.[15] For the same reason we do not necessarily expect to see the coefficients on historical sites' distance bands declining in absolute terms as we move from sites which closed 0-10 years previously through to sites which closed 20+ years ago. Historical sites have been poorly managed judged by today's standards and we speculate, less effort taken to remediate sites following their closure.[16]

Note that because of missing information, particularly for historical sites, we are not able to investigate in an entirely satisfactory manner whether disamenity impacts depend on the nature of the waste contained in these sites.[17] Furthermore no information is available on the

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[15] Control measures may include venting landfill gas or burning it off. It is also necessary to use leachate control methods such as borehole pumps for extracting the leachate in order to prevent groundwater pollution. Due to lack of data there is little evidence whether historic landfill sites studied had taken either gas or leachate control measures.

[16] We contacted Birmingham City Council who acknowledge that historical landfill sites were managed less well than at present and post closure remediation would have been to a lower standard than today. Whilst landfill sites which closed after 16 July 2001 are subject to the requirements of the Landfill Directive nationally only some sites which closed before 16 July 2001 are regulated for aftercare management and are subject to closed landfill review by the Environmental Agency. In fact, none of the landfills in Birmingham are subject to review.

[17] For the purposes of identifying the disamenity impacts of different types of waste we estimate a conventional specification of the form

$$\ln(PRICE) = \alpha + \sum_k \beta_k Z_k + \gamma DIST + \sum_m \varphi_m X_m DIST$$

where *DIST* is distance to the nearest active landfill site and X_m is a set of 3 dummy variables identifying different types of landfill site (co-disposal sites, non-biodegradable waste sites, construction / demolition / dredging sites and restricted industrial waste sites). Results indicate that residents are particularly sensitive to proximity to landfills specialising in non-biodegradable waste and restricted industrial waste. For these types of landfill site property amount of waste contained in these sites (although there is information on the average period of time for which they were or have been operational contained in Tables 2 and 3).

Lastly, we compare our results with those obtained from the model specification most typically encountered in the literature. This 'conventional' model (Model 6) includes DISTANCE to the nearest landfill regardless of whether the landfill was active or historical and the same variable but interacted with the dummy variable ACTIVE denoting obviously, an active landfill.[18] Both of these variables are positively signed and statistically significant at the one percent level of confidence. A one kilometre increase in distance from the nearest historic site increases house prices by 3.2 percent or £1,911 on average. But active sites have an even greater disamenity impact with every additional kilometre increasing property values by 10.2 percent or £6,011 on average.

In order to discriminate between these two different methods of representing the disamenity impact of landfill sites a further specification (not shown) includes both the three kilometre and one kilometre distance bands for active and historical sites respectively, as well as the DISTANCE and ACTIVE × DISTANCE variables. Eliminating the variables DISTANCE and ACTIVE × DISTANCE from this combined model results in an F(2, 10684) statistic of 5.32 with a P value of 0.005. Eliminating the distance bands for the active and historical sites however, results in an F(5, 10684) statistic of 10.64 with a P value of 0.000. Such results point to two things. First, they confirm the importance of accounting for a situation in which properties are simultaneously located close to more than one landfill site as well as distinguishing between historical landfill sites that closed at different points in the past. Second, they serve to remind us that our distance bands measure only the 'average' disamenity impact within a particular radius of the landfill site and not the distance-decay. Adding additional distance bands 0-1km and 0-2km for active landfills renders DISTANCE and ACTIVE × DISTANCE jointly insignificant (results not shown) but the coefficients on these extra variables are poorly determined.

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prices increase by 1.7 percent and 0.7 percent for each kilometre further away from the site respectively.

[18] Note that of 10,792 observations only 94 properties were nearer to active sites than historic ones.

Table 5: Econometric results

Method: OLS

Number of observations: 10,792

Dependent variable: Log(Price)

Structural Variables				
	Model 1	Model 2	Model 3	Model 4
Floor Area	0.0041***	0.0042***	0.0041***	0.0042***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Garden Area	0.0004***	0.0004***	0.0004***	0.0004***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Sales Date	0.0002***	0.0002***	0.0002***	0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Age	-0.0223***	-0.0234***	-0.0231***	-0.0228***
	(0.0035)	(0.0035)	(0.0035)	(0.0035)
Beds	0.0089*	0.0080*	0.0088*	0.0083*
	(0.0048)	(0.0048)	(0.0048)	(0.0048)
WCs	0.0107*	0.0100*	0.0113*	0.0114**
	(0.0058)	(0.0058)	(0.0058)	(0.0058)
Floors	-0.1503***	-0.1501***	-0.1496***	-0.1510***
	(0.0120)	(0.0121)	(0.0121)	(0.0121)
Garage	0.0733***	0.0735***	0.0729***	0.0735***
	(0.0061)	(0.0062)	(0.0062)	(0.0062)
Detached	0.0164	0.0181	0.0187	0.0183
Bungalow	(0.0245)	(0.0245)	(0.0246)	(0.0246)
Semi-Detached	-0.0963***	-0.0911***	-0.0920***	-0.0913***
Bungalow	(0.0283)	(0.0284)	(0.0284)	(0.0284)
End Terrace	-0.2468**	-0.2454**	-0.2478**	-0.2496**
Bungalow	(0.1055)	(0.1056)	(0.1058)	(0.1059)
Terrace	-0.0841	-0.1062	-0.1085	-0.0975
Bungalow	(0.1355)	(0.1357)	(0.1359)	(0.1360)
Detached House	0.1289***	0.1306***	0.1285***	0.1289***
	(0.0095)	(0.0095)	(0.0095)	(0.0095)

End Terrace House	-0.0846***	-0.0869***	-0.0869***	-0.0867***
	(0.0084)	(0.0084)	(0.0084)	(0.0084)
Terrace House	-0.0980***	-0.0981***	-0.0985***	-0.0989***
	(0.0074)	(0.0074)	(0.0074)	(0.0074)
BG1 Unrenovated cottage pre 1919	-0.0509	-0.0317	-0.0486	-0.0461
	(0.1172)	(0.1174)	(0.1176)	(0.1176)
BG2 Renovated cottage pre 1919	0.2363***	0.2413***	0.2392***	0.2358***
	(0.0839)	(0.0840)	(0.0841)	(0.0842)
BG3 Small "industrial" pre 1919	-0.0881***	-0.0905***	-0.0866***	-0.0875***
	(0.0189)	(0.0190)	(0.0190)	(0.0190)
BG4 Medium "industrial" pre 1919	-0.0260*	-0.0207	-0.0237*	-0.0242*
	(0.0140)	(0.0140)	(0.0140)	(0.0140)
BG5 Large terrace pre 1919	0.0581*	0.0623*	0.0564*	0.0581*
	(0.0329)	(0.0329)	(0.0330)	(0.0330)
BG8 Small "villa" pre 1919	0.0725***	0.0822***	0.0768***	0.0767***
	(0.0199)	(0.0200)	(0.0200)	(0.0200)
BG9 Large "villa" pre 1919	0.0742***	0.0820***	0.0804***	0.0809***
	(0.0282)	(0.0282)	(0.0283)	(0.0283)
BG10 Large detached pre 1919	-0.3294***	-0.3348***	-0.3236***	-0.3286***
	(0.0451)	(0.0451)	(0.0452)	(0.0452)

BG19 Houses 1908 to 1930	0.1019***	0.1072***	0.1025***	0.1064***
	(0.0235)	(0.0235)	(0.0236)	(0.0236)
BG20 Subsidy houses 1920s and 30s	-0.0983***	-0.0943***	-0.1012***	-0.1008***
	(0.0096)	(0.0096)	(0.0096)	(0.0096)
BG24 Large houses 1919-45	0.1072***	0.1036***	0.1079***	0.1082***
	(0.0212)	(0.0212)	(0.0212)	(0.0212)
BG25 Individual houses 1919-45	-0.6639***	-0.6524***	-0.6500***	-0.6551***
	(0.1105)	(0.1106)	(0.1108)	(0.1109)
BG30 Standard houses 1945-53	-0.1200***	-0.1304***	-0.1278***	-0.1242***
	(0.0139)	(0.0139)	(0.0139)	(0.0140)
BG31 Standard houses post 1953	-0.0533***	-0.0582***	-0.0559***	-0.0550***
	(0.0160)	(0.0160)	(0.0160)	(0.0160)
BG32 Large houses post 1953	0.0548**	0.0557**	0.0529**	0.0561***
	(0.0216)	(0.0216)	(0.0217)	(0.0217)
BG35 Individual houses post 1945	0.0294	0.0281	0.0370	0.0324
	(0.0684)	(0.0684)	(0.0686)	(0.0686)
BG36 "Town Houses" post 1950	-0.2444***	-0.2427***	-0.2347***	-0.2281***
	(0.0399)	(0.0400)	(0.0400)	(0.0401)
Neighbourhood Variables				
Age60	0.0001	0.0005	0.0004	0.0005
	(0.0005)	(0.0005)	(0.0005)	(0.0005)

Unemployment	-0.0088***	-0.0089***	-0.0088***	-0.0087***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
White	0.0045***	0.0045***	0.0040***	0.0041***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Asian	0.0054***	0.0051***	0.0052***	0.0052***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Family with children	0.0001	0.0003	0.0002	0.0002
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Accessibility Variables				
Primary Schools	0.1618***	0.1602***	0.1613***	0.1676***
	(0.0173)	(0.0174)	(0.0174)	(0.0173)
Shops	-0.0140***	-0.0106***	-0.0116***	-0.0113***
	(0.0033)	(0.0032)	(0.0032)	(0.0032)
Rail Station	-0.0012***	-0.0007***	-0.0008***	-0.0008***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Park	-0.0002	0.0000	-0.0002	-0.0000
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
University / Queen Elizabeth Hospital	-0.0024***	-0.0024***	-0.0021***	-0.0022***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
CBD	0.0008	0.0018	0.0006	0.0010
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
Motorway Junction	0.0035***	0.0028**	0.0029**	0.0028**
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Airport	-0.0071***	-0.0068***	-0.0072***	-0.0070***
	(0.0010)	(0.0010)	(0.0010)	(0.0010)
Mosque	0.0358***	0.0281***	0.0300***	0.0306***
	(0.0042)	(0.0043)	(0.0043)	(0.0043)
Industry A	0.0424***	0.0435***	0.0466***	0.0459***
	(0.0045)	(0.0046)	(0.0047)	(0.0047)

Industry B	-0.0049	-0.0007	0.0004	-0.0022
	(0.0069)	(0.0068)	(0.0068)	(0.0070)
Motorway	0.0052	0.0026	0.0088*	0.0121**
	(0.0047)	(0.0048)	(0.0050)	(0.0050)
Road A	-0.0265***	-0.0289***	-0.0265***	-0.0256***
	(0.0081)	(0.0081)	(0.0082)	(0.0081)
Road B	-0.0116*	-0.0051	-0.0091	-0.0062
	(0.0063)	(0.0064)	(0.0064)	(0.0064)
Minor Road	-0.2609**	-0.2512*	-0.2712**	-0.2534*
	(0.1324)	(0.1326)	(0.1328)	(0.1330)
Railway	0.0178**	0.0138**	0.0058	0.0075
	(0.0069)	(0.0069)	(0.0069)	(0.0070)
Environmental Variables				
Water View	0.0000	0.0001	0.0000	0.0000
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Park View	-0.0000	0.0000	0.0000	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Road View	0.0001	0.0001	0.0001	0.0001
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Rail View	-0.0018***	-0.0019***	-0.0019***	-0.0018***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Road Noise	-0.0017***	-0.0018***	-0.0018***	-0.0018***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Rail Noise	-0.0029	-0.0018	-0.0023	-0.0025
	(0.0019)	(0.0020)	(0.0020)	(0.0020)
Airport Noise	0.0011	0.0022	0.0032	0.0032
	(0.0026)	(0.0026)	(0.0026)	(0.0026)
NO_2	0.0006***	0.0005***	0.0006***	0.0005***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
CO	0.0089	0.0104	0.0095	0.0132*
	(0.0067)	(0.0067)	(0.0067)	(0.0068)
Landfill Variables				

0-1 km			
Active	-0.0502		
	(0.0539)		
Historic	-0.0277***		
1-10 years	(0.0077)		
Historic	-0.0211***		
11-20 years	(0.0073)		
Historic	-0.0364***		
20+ years	(0.0047)		
Historic	0.0028		
Not Known	(0.0051)		
0-2 km			
Active		0.0481***	
		(0.0183)	
Historic		0.0004	
1-10 years		(0.0049)	
Historic		-0.0328***	
11-20 years		(0.0048)	
Historic		-0.0012	
20+ years		(0.0034)	
Historic		0.0017	
Not Known		(0.0032)	
0-3 km			
Active			-0.0345***
			(0.0113)
Historic			0.0130***
1-10 years			(0.0042)
Historic			-0.0104**
11-20 years			(0.0042)
Historic			0.0083***
20+ years			(0.0030)
Historic			0.0001

Not Known			(0.0032)	
0-4 km				
Active				-0.0059
				(0.0081)
Historic				0.0085***
1-10 years				(0.0028)
Historic				-0.0017
11-20 years				(0.0034)
Historic				0.0069***
20+ years				(0.0024)
Historic				-0.0025
Not Known				(0.0026)
Constant	10.5849***	10.5952***	10.5115***	10.4564***
	(0.0921)	(0.0922)	(0.0927)	(0.0944)
Diagnostic tests				
N	10792	10792	10792	10792
R^2	0.7668	0.7663	0.7656	0.7653
Adjusted R^2	0.7645	0.7640	0.7633	0.7630
AIC	-752.0923	-727.3822	-695.1177	-683.5342
Jarque-bera	4877	4941	4963	5000***
Multicollinearity	0.23319117	0.23372572	0.23442552	0.23467728
Breusch-Pagan	0.11	0.59	0.09	0.23
Ramsey RESET	51.20***	53.65***	54.67***	52.62***

*Notes: Semi-detached houses, BG21 (Standard houses 1919-45), and the proportion of black residents are omitted as the baseline. Statistical significance is indicated by *, **, *** for the 0.1, 0.05 and 0.01 levels of significance respectively. Wards are included but their coefficients are not displayed.*

Table 6: Best distance band for disamenity impacts from active and historic landfills

	Historic 0-1 km	**Historic 0-2 km**	**Historic 0-3 km**	**Historic 0-4 km**
Active 0-1 km	0.7645	0.7638	0.7630	0.7630
Active 0-2 km	0.7645	0.7639	0.7633	0.7632
Active 0-3 km	<u>0.7646</u>	0.7640	0.7632	0.7631
Active 0-4 km	0.7645	0.7638	0.7630	0.7630

Table 7: Econometric results

Method: OLS

Number of observations: 10,792

Dependent variable: Log(Price)

Structural Variables		
	Model 5	Model 6
Floor Area	0.0041***	0.0041***
	(0.0001)	(0.0001)
Garden Area	0.0004***	0.0004***
	(0.0000)	(0.0000)
Sales Date	0.0002***	0.0002***
	(0.0000)	(0.0000)
Age	-0.0224***	-0.0225***
	(0.0035)	(0.0035)
Beds	0.0088*	0.0087*
	(0.0048)	(0.0048)
WCs	0.0107*	0.0109*
	(0.0058)	(0.0058)
Floors	-0.1499***	-0.1507***
	(0.0120)	(0.0121)
Garage	0.0736***	0.0734***
	(0.0061)	(0.0062)
Detached	0.0169	0.0162
Bungalow	(0.0245)	(0.0245)
Semi-Detached	-0.0972***	-0.0924***
Bungalow	(0.0283)	(0.0284)
End Terrace	-0.2468**	-0.2456**
Bungalow	(0.1055)	(0.1057)
Terrace	-0.0909	-0.0904
Bungalow	(0.1355)	(0.1357)
Detached House	0.1286***	0.1298***
	(0.0095)	(0.0095)

End Terrace House	-0.0847***	-0.0874***
	(0.0084)	(0.0084)
Terrace House	-0.0981***	-0.0997***
	(0.0074)	(0.0074)
BG1 Unrenovated cottage pre 1919	-0.0488	-0.0392
	(0.1172)	(0.1174)
BG2 Renovated cottage pre 1919	0.2367***	0.2372***
	(0.0839)	(0.0840)
BG3 Small “industrial” pre 1919	-0.0857***	-0.0898***
	(0.0189)	(0.0189)
BG4 Medium “industrial” pre 1919	-0.0248*	-0.0251*
	(0.0140)	(0.0140)
BG5 Large terrace pre 1919	0.0599*	0.0605*
	(0.0329)	(0.0329)
BG8 Small “villa” pre 1919	0.0747***	0.0773***
	(0.0199)	(0.0200)
BG9 Large “villa” pre 1919	0.0747***	0.0776***
	(0.0282)	(0.0283)
BG10 Large detached pre 1919	-0.3291***	-0.3340***
	(0.0451)	(0.0452)

BG19 Houses 1908 to 1930	0.1013***	0.1046***
	(0.0235)	(0.0235)
BG20 Subsidy houses 1920s and 30s	-0.0986***	-0.1001***
	(0.0096)	(0.0096)
BG24 Large houses 1919-45	0.1077***	0.1082***
	(0.0212)	(0.0212)
BG25 Individual houses 1919-45	-0.6607***	-0.6576***
	(0.1105)	(0.1107)
BG30 Standard houses 1945-53	-0.1205***	-0.1232***
	(0.0139)	(0.0139)
BG31 Standard houses post 1953	-0.0528***	-0.0550***
	(0.0160)	(0.0160)
BG32 Large houses post 1953	0.0540**	0.0553**
	(0.0216)	(0.0216)
BG35 Individual houses post 1945	0.0274	0.0287
	(0.0683)	(0.0685)
BG36 "Town Houses" post 1950	-0.2414***	-0.2441***
	(0.0399)	(0.0400)
Neighbourhood Variables		
Age60	-0.0000	0.0003
	(0.0005)	(0.0005)

Unemployment	-0.0088***	-0.0090***
	(0.0005)	(0.0005)
White	0.0045***	0.0047***
	(0.0007)	(0.0007)
Asian	0.0055***	0.0057***
	(0.0007)	(0.0007)
Family with children	0.0001	0.0001
	(0.0005)	(0.0005)
Accessibility Variables		
Primary Schools	0.1603***	0.1613***
	(0.0173)	(0.0173)
Shops	-0.0142***	-0.0130***
	(0.0033)	(0.0032)
Rail Station	-0.0012***	-0.0009***
	(0.0003)	(0.0003)
Park	-0.0001	-0.0000
	(0.0003)	(0.0003)
University / Queen Elizabeth Hospital	-0.0024***	-0.0023***
	(0.0003)	(0.0003)
CBD	0.0009	0.0008
	(0.0014)	(0.0013)
Motorway Junction	0.0032***	0.0032***
	(0.0011)	(0.0011)
Airport	-0.0072***	-0.0067***
	(0.0010)	(0.0010)
Mosque	0.0355***	0.0324***
	(0.0042)	(0.0042)
Industry A	0.0436***	0.0433***
	(0.0045)	(0.0044)

Industry B	-0.0040	-0.0027
	(0.0069)	(0.0068)
Motorway	0.0032	0.0090*
	(0.0047)	(0.0046)
Road A	-0.0248***	-0.0267***
	(0.0081)	(0.0081)
Road B	-0.0121*	-0.0094
	(0.0063)	(0.0063)
Minor Road	-0.2641**	-0.2601**
	(0.1324)	(0.1326)
Railway	0.0159**	0.0104
	(0.0070)	(0.0068)
Environmental Variables		
Water View	0.0000	0.0000
	(0.0003)	(0.0003)
Park View	-0.0000	0.0000
	(0.0001)	(0.0001)
Road View	0.0001	0.0001
	(0.0003)	(0.0003)
Rail View	-0.0019***	-0.0019***
	(0.0007)	(0.0007)
Road Noise	-0.0017***	-0.0018***
	(0.0006)	(0.0006)
Rail Noise	-0.0028	-0.0021
	(0.0019)	(0.0020)
Airport Noise	0.0011	0.0027
	(0.0026)	(0.0025)
NO_2	0.0006***	0.0006***
	(0.0002)	(0.0002)
CO	0.0085	0.0116*
	(0.0067)	(0.0067)
Landfill Variables		

0-1 km	
Active	
Historic	-0.0273***
1-10 years	(0.0077)
Historic	-0.0221***
11-20 years	(0.0073)
Historic	-0.0355***
20+ years	(0.0047)
Historic	0.0025
Not Known	(0.0051)
0-2 km	
Active	
Historic	
1-10 years	
Historic	
11-20 years	
Historic	
20+ years	
Historic	
Not Known	
0-3 km	
Active	-0.0286***
	(0.0111)
Historic	
1-10 years	
Historic	
11-20 years	
Historic	
20+ years	
Historic	

Not Known		
0-4 km		
Active		
Historic		
1-10 years		
Historic		
11-20 years		
Historic		
20+ years		
Historic		
Not Known		
Distance		0.0324***
		(0.0055)
Distance ×		0.0695***
Active		
		(0.0205)
Constant	10.6063***	10.4569***
	(0.0925)	(0.0914)
Diagnostic tests		
N	10792	10792
R^2	0.7669	0.7660
Adjusted R^2	0.7646	0.7638
AIC	-757.9508	-721.0687
Jarque-bera	4896***	4896***
Multicollinearity	0.23306462	0.23399254
Breusch-Pagan	0.10	0.29
Ramsey RESET	51.70***	52.24***

*Notes: Semi-detached houses, BG21 (Standard houses 1919-45), and the proportion of black residents are omitted as the baseline. Statistical significance is indicated by *, **, *** for the 0.1, 0.05 and 0.01 levels of significance respectively. Wards are included but their coefficients are not displayed.*

7. Conclusions

This study seeks to estimate the impact of active and historic landfill sites on property prices for the city of Birmingham. Although numerous papers have estimated such impacts none appear to have done so in the context of a situation where properties are very often located near to more than one landfill site. Data for Birmingham suggests that such occurrences are frequent and that this significantly affects the perceived impact of landfill sites on property prices. Results also suggest that the discernible impact of active and historical landfill sites on house prices extends over a different geographical range: 0-3 km for active landfill sites and 0-1 km for historical landfill sites. Importantly, historical landfill sites continue to depress property prices more than 20 years after their closure.

Although the estimates we obtain are not directly comparable to Bateman et al. (2004) due to differences in model specification, compared to the only other United Kingdom based estimate of the average reduction in property prices due to landfill disamenities our work suggests a 2.6 percent reduction within 3 kilometres rather than the 7 percent reduction within 0.25 miles and further 2 percent reduction within 0.25-0.5 miles of operational landfills suggested by Cambridge Econometrics et al. (2003). Put differently, whereas our estimates point to a reduction of 2.6 percent over an area of 28.3 km^2 the Cambridge Econometrics et al. (2003) study suggests a reduction of 7 percent over an area of 0.5 km^2 and a reduction of 2 percent over a further area of 1.5 km^2. Our corresponding estimates for historical landfill sites, for which no United Kingdom based comparator studies are available, indicate an impact of 2.4 to 3.4 percent over a geographical area of 3.1 km^2 depending on how long ago the landfill closed.

These figures might, with further elaboration, provide a basis for setting the correct level of the landfill tax, the main driver of landfill diversion in the United Kingdom. However, there are some limitations. For many historical landfill sites it is unknown precisely when they closed or what they contain. Likewise there is no information available on the size of landfills or the rate at which currently active sites accept waste. Other studies by contrast, have shown that the size of a landfill is an important determinant of the overall disamenity impact. In addition, windblown material and odour can affect households far distant from a landfill and this invites us to consider the directional impacts of landfill in a further study on landfill disamenities. Perhaps the most important caveat however is the sensitivity of the results to assumptions about the geographical extent of landfill disamenity impacts.

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